Unit 1 – Lesson 1

Matter States

States of Matter and Their Properties

Scientists try to observe the patterns and common characteristics shared among the materials around us. This makes it easier to classify and study them. For example, elements or essential compounds, living things, and organisms.
The diagram below shows how matter is defined and classified according to its physical states:

Matter		
Definition:	**Classification by Physical State:**	**Mass:**
Anything that has mass and occupies space.	Matter can be classified into three states: • Solid materials • Liquid materials • Gaseous materials	A fixed (definite) amount that does not change from one place to another.

Question: Think and Answer

Do all these things have the properties of matter?

a) copper
b) Ruler
c) Computer
d) Music

Copper, ruler and the computer are forms of matter, and have mass and occupy space.
Answer: (d) Music is not matter.

Differences in the Properties of Materials According to Their Physical State

اختلاف خصائص المواد حسب حالتها الفيزيائية

Properties of Matter

1. **Shape & Ability to Flow** الشكل وقابلية الانسياب
2. **Volume & Ability to Compress** الحجم وقابلية الانضغاط
3. **Ability to Spread (diffusion)** قابلية الانتشار

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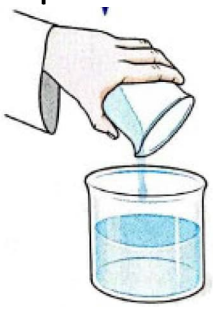
1. Property of Shape and Ability to Flow (Fluidity)

When transferring different materials into containers, we notice:

Solid Materials	Liquid Materials	Gaseous Materials
Examples: Wood and iron **Solids do not flow and do not change shape (they keep a fixed shape and volume).**	**Examples: Water and oil**  Liquids flow and change shape (they take the shape of the container).	**Examples: Air and oxygen** **Gases flow and change shape (they also take the shape of the container).**

We conclude that:

- **Solids** do not change their shape when moved from one place to another.
- **Liquids and gases** have the ability to flow and change their shape based on the shape of the container holding them.

  So, liquids and gases are classified in one category known as fluids.

Fluids: Materials that can flow and take the shape of their container.

Flow (Fluidity): Ability of fluids to move and flow easily.

Be Careful!

* Liquids differ in their ability to flow depending on their viscosity.

* During flow, the **volume** of the **liquid remains unchanged**, while the volume of **the gas changes**.

Remember :

Viscosity:

A measure of a liquid's resistance to flow (e.g., honey has high viscosity; water has low viscosity).

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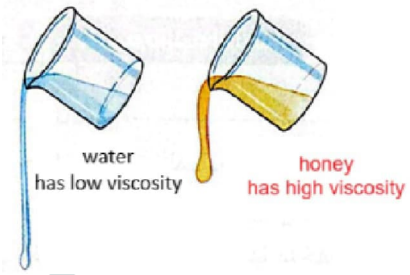
Quick Questions:

Q: Why is the movement of sand not considered flow?

Because sand is **not a fluid**, and the movement of its particles from one place to another **does not change the shape of the grains.**

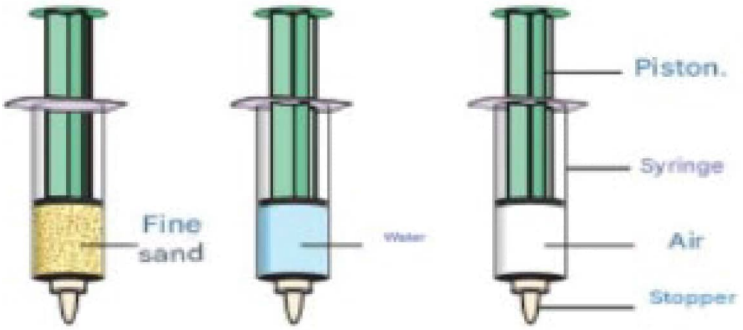
Give a reason: The difference in flow rate between honey and water.

Because honey's viscosity is higher than water's, and flowability decreases as viscosity increases.



2. Property of Volume and Compressibility

When pressing pistons in three sealed syringes containing equal volumes of different materials, it is observed that:



Solid Materials	Liquid Materials	Gaseous Materials
Example: Fine sand	Example: Water	Example: Air
Incompressible	Incompressible	Compressible
Volume remains constant (doesn't change)	Volume remains constant (doesn't change)	Volume decreases (takes the container's shape)

Conclusions from the Above:

- **Solid and liquid materials** have a **fixed volume** and are **incompressible**.
- **Gaseous materials** do **not** have a fixed volume and are **compressible**.

Compressibility: The ability to reduce the volume of **gases** when pressure is increased.

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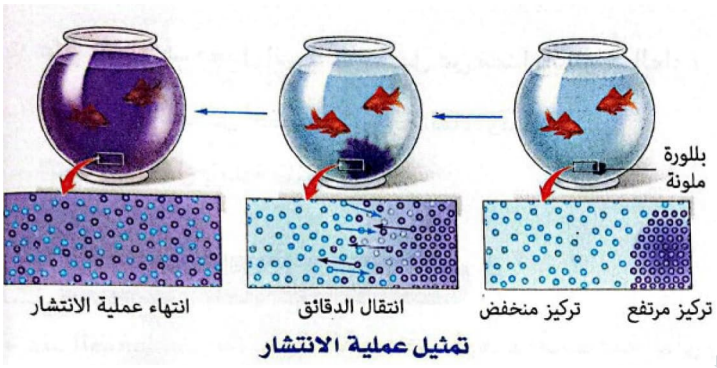
3. Property of Diffusion

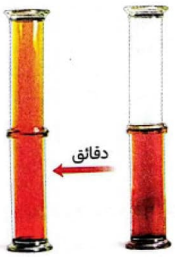
Definition:

The movement of particles **from** an area of **high** concentration **to** an area of **low** concentration.



تمثيل عملية الانتشار

Diffusion Rates:

State of Matter	Diffusion Speed	Example
Gaseous Materials	Very fast	Bromine vapor spreading in air 
Liquid Materials	Medium speed	Potassium permanganate dissolving in water
Solid Materials	Very slow	Dye spreading in a sponge

Conclusions from the Above:

The speed of particle diffusion **depends on** the physical state of the medium through which it spreads.

Diffusion Speed: Gas (O_2) > Liquid (H_2O) > Solid (Iron)

Important Notes:

Diffusion speed **depends on** the temperature of the medium, increasing as temperature rises.

Lighter gas particles diffuse faster than heavier ones.

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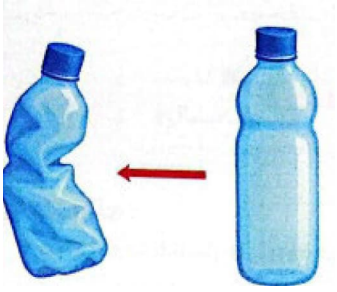
Summary of Matter Properties in the Three States

Property	Gaseous State	Liquid State	Solid State
Shape Change	Changes shape (takes container's shape)	Changes shape (takes container's shape)	Fixed shape
Flowability	Flows easily	Flows (depends on viscosity)	Does not flow
Compressibility	Compressible	Incompressible	Incompressible
Volume Change	Changes volume (takes container's volume)	Fixed volume	Fixed volume
Diffusion Speed	Very fast	Medium speed	Extremely slow

Evaluate your understanding

From the opposite figure:



Which of the following expresses what happened inside the bottle?

a) Compression of air.

b) Diffusion of air.

c) Increase in air volume.

d) Flow of air.

The bottle is closed, so

Did not occur: Air diffusion or Increase in air volume

Explanation:
The deformation of the bottle is due to pressure being applied, causing the air inside to compress.

Correct answer:
✓ Air compression

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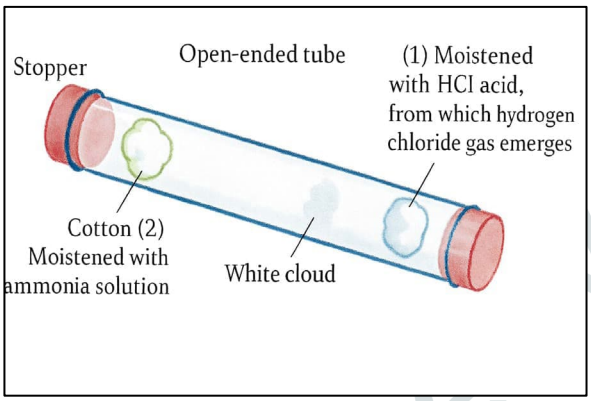
Experiment Observations:

The figure shows a diffusion experiment with two gases (ammonia and hydrogen chloride), forming a white cloud where they meet.


Stopper
Open-ended tube
(1) Moistened with HCl acid, from which hydrogen chloride gas emerges
Cotton (2) Moistened with ammonia solution
White cloud

Questions: Which gas diffuses faster? Explain.

Answer: Ammonia gas diffuses faster than hydrogen chloride, as the meeting point is closer to cotton (1).

Which gas has heavier molecules? Explain.

Answer: Hydrogen chloride molecules are heavier, as evidenced by their slower diffusion rate.

Evaluation (1)

Multiple Choice Questions:

1. **Solids and liquids are similar in their _____.**
   (1) Fixed shape
   (2) Fixed volume
   (3) Fixed flow
   (4) Fast diffusion

2. **Inflating a balloon with air shows that air _____.**
   (1) Has mass
   (2) Can be seen
   (3) Occupies space

3. **The given table classifies materials based on their _____.**

Group (1)	Group (2)	Group (3)
Water Vapor	Dew	Iron
Air	Raindrops	Snow

   (1) Physical state
   (2) Material type
   (3) Compressibility
   (4) Specific shape

(4) An empty, closed container has a volume of 250 cm^3. 40 cm^3 of the air inside it was withdrawn.

What is the volume of the remaining air in the container?

A) 200 cm^3 B) 210 cm^3 C) 250 cm^3 D) 290 cm^3

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Short Answer Questions:

(a) Matter exists in three fundamental states:

1. **Two common properties of all matter:**
2. **Property shared by liquids and gases (not solids):**

(b) Write what each of the following statements indicates:

(1) Everything that has mass and occupies space. (.....)

(2) Substances that take the shape of the container they are in. (.....)

(3) The movement of particles from an area of higher concentration to an area of lower concentration. (.....)

(4) The ability of fluids to flow easily. (.....)

(b) Define the following terms:

1. **Matter:** .....
2. **Fluids:** .....
3. **Diffusion:** .....
4. **Flowability:** .....

(c) Explain scientifically:

1. **Flower scent is stronger during daytime:**
   - .....
2. **Hydrogen is compressible, while oil is not:**

   .....

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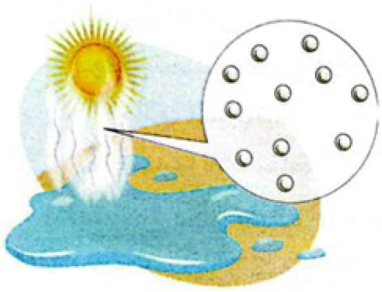
The Particle Model of Matter

- **All matter is made up of small units called particles.**
- **It is one of the theories that has succeeded in explaining much of the behavior of matter and its properties, known as the particulate theory of matter.**

Accumulated knowledge:

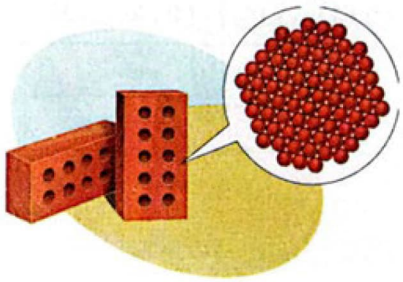
- **The particles of matter are monatomic molecules or polyatomic molecules.**
- **A polyatomic molecule consists of two or more atoms chemically bonded together.**

Assumptions of the Particle Theory of Matter



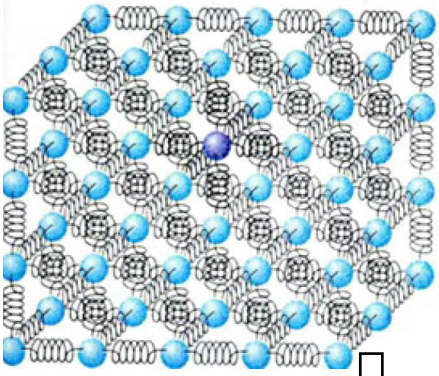
Gaseous Matter Particles

Liquid Matter Particles



Solid Matter Particles

1. Matter consists of very small particles that cannot be seen with the naked eye.
2. The particles of the same substance are identical, but they differ from one substance to another.
3. The particles of matter store **potential energy** due to the forces of attraction between them.
4. There are intermolecular spaces between the particles of matter, which differ depending on its physical state.



5. The particles of matter have **kinetic energy**, as they are in a state of continuous motion.
6. The way the particles move and their speed differs with the different states of matter.

- The balls represent the particles of solid matter.
- The spring represents the force of attraction between the particles.
- The particles of solid matter vibrate around their fixed positions and store energy in the form of potential energy.

The difference in the strength of the bonds between the particles of matter (the cause) leads to a difference in their behavior and properties (the result), which will be explained as follows:

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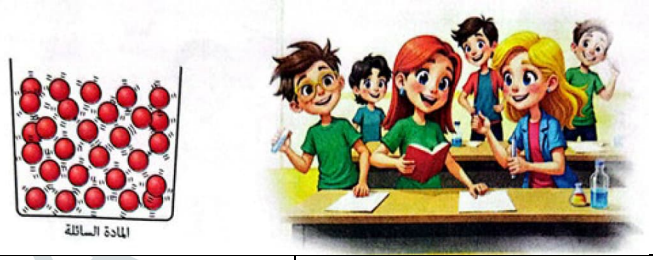
Behavior and Properties of Solid Materials سلوك وخواص المواد الصلبة

Cause (السبب)	Result (النتيجة)
The **force of attraction** between the particles is **very strong**.	The particles of solid matter are **arranged and tightly bound** to each other, giving them a **fixed shape** that is **not able to flow**.
The **intermolecular spaces** between the particles are **very small**.	Solid matter has a **fixed volume** and is **not compressible**.
The particles **vibrate** in their positions **without moving** to other positions.	**Diffusion** through solid matter is **very slow**.

Give reason: Solid materials have a definite shape and volume.

Because the **forces of attraction** between their particles are very strong and the **intermolecular spaces** between them are very small.

Behavior and Properties of Liquid Materials



Cause (السبب)	Result (النتيجة)
The **forces of attraction** between the particles are **relatively weak**, but sufficient to hold them together.	Liquid matter **does not have a fixed shape**, is able to flow, and **takes the shape of its container**.
The **intermolecular spaces** between the particles are **relatively large**.	Liquid matter has **a fixed volume** and is **not compressible.**
The particles **move freely** within the container they are in.	**Diffusion** through liquid matter occurs at **a moderate speed.**

Give reason: Liquid materials have an indefinite shape and a definite volume.

Because the **forces of attraction** between their particles are relatively weak and the **intermolecular spaces** between them are relatively large.

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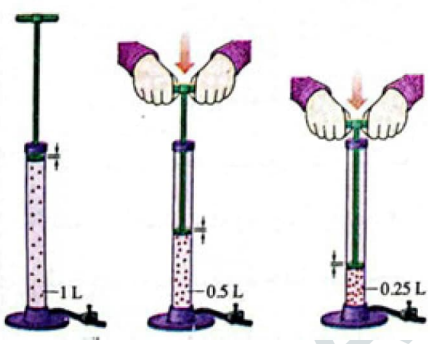
Behavior and Properties of Gaseous Materials

Cause (السبب)	Result (النتيجة)
The **forces of attraction** between the particles are **very weak**.	Gaseous matter **does not have a fixed shape**, is **able to flow, and takes the shape of its container**.
The intermolecular spaces between the particles **are very large**.	Gaseous matter **does not have a fixed volume**, is compressible, and **takes the shape of its container**.
The particles **move randomly** and with **complete free** in all directions.	**Diffusion** through gaseous matter is **very fast**.

Give reason: Gaseous materials have neither a definite shape nor a definite volume.

Because **the forces of attraction** between their particles are very weak, and the **intermolecular spaces** between them are very large.



The volume of gases decreases with pressure

Compressibility of gases reduces the intermolecular spaces between their particles, which leads to a decrease in the volume of the gas, **without changing the volume of the particles themselves.**

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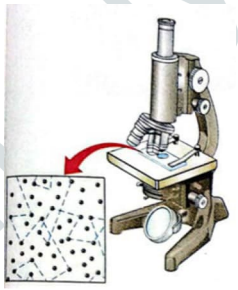
Brownian Motion

- **Its Discovery:** The scientist Robert Brown discovered in 1827 that pollen grains suspended in water are in a state of continuous random motion in all directions. This motion was named Brownian motion relative to the scientist Brown.



- **Its Cause:** The collision between the particles of the fluid (liquid or gas) and the relatively large particles present in it, such as pollen grains in water or dust in the air, leads to the random movement of the pollen or dust particles in all directions.

Brownian Motion: The random motion in all directions of relatively large particles suspended in a fluid as a result of their continuous collision with the fluid's particles.

Question & Answer

Explain the following in light of the postulates of the particulate theory of matter.

Image/Phenomenon	Explanation
Difficulty of breaking a piece of rock	Because the **forces of attraction** between the particles of the solid rock are very strong and **the intermolecular spaces** are very small, which makes the particles very tightly bound to each other.
Dissolving table salt in water	Because the forces of attraction between the particles of liquid water are relatively weak and the intermolecular spaces between them are relatively large, the table salt particles occupy these spaces.
The spread of smoke from a candle wick in the air	Because the forces of attraction between the air particles are very weak and the intermolecular spaces are very large, the smoke particles spread through them.

In light of the preceding, the properties and behavior of matter in its three states can be summarized in light of the particulate model of matter, as follows:

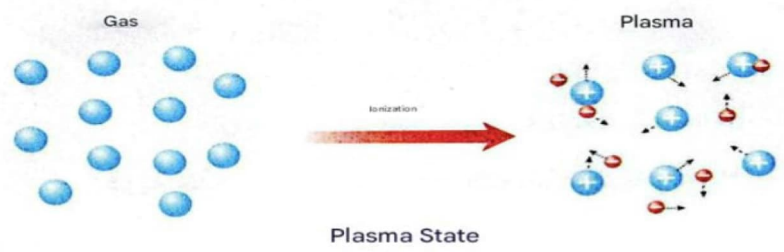
States of Matter & their Properties and the Resulting Behavior	Solid State	Liquid State	Gaseous State
Attractive Forces between particles	Very Strong	Relatively Weak	Very Weak
Resulting Behavior based on this property	Has a fixed shape (does not take the shape of the container) and is not able to flow.	Has an unfixed shape (takes the shape of the container) and is able to flow.	Has an unfixed shape (takes the shape of the container) and is able to flow.
Intermolecular Spaces	Very Small	Relatively Large	Very Large
Resulting Behavior based on this property	Has a fixed volume and is not compressible.	Has a fixed volume and is not compressible.	Has an unfixed volume and is compressible.
Particle Movement	Particles vibrate in their positions only.	Particles move with relative freed within the container.	Particles move randomly with complete freedom.
Resulting Behavior based on this property	Diffusion through it is very slow.	Diffusion through it is at a moderate speed.	Diffusion through it is very fast.

plasma state:

The fourth state of matter in which gases are ionized, i.e., they transform into positively charged ions and free, negatively charged electrons.

This state is known as the plasma state, and it is considered the fourth state of matter.

When **gases are intensely heated** to thousands or millions of degrees (of heat), **they become ionized**.



Gas -> Ionization -> Plasma State

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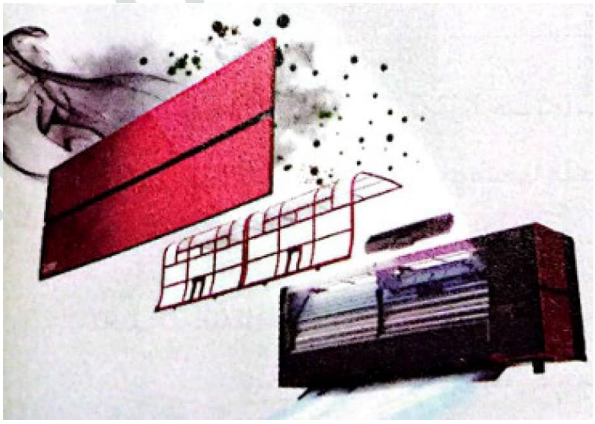
- **Characteristics of the Plasma State:**
  Its high electrical conductivity.
- **Forms of its Presence:**
  1. Matter in outer space exists in a plasma state, as in the sun, stars, and cosmic nebulae.
  2. Lightning.
  3. The polar aurora.

Aurora Phenomenon

Technological Application

The plasma state is used in air conditioning systems to improve air quality in enclosed spaces.

- **How it Works:**
  1. Gases are passed through a high-voltage electric field to transform their atoms into positively charged ions and negatively charged electrons.
  2. The charged gas ions work to break down the molecules of harmful air pollutants, germs, and viruses, which leads to making the air purer.



Air conditioner that works with plasma.

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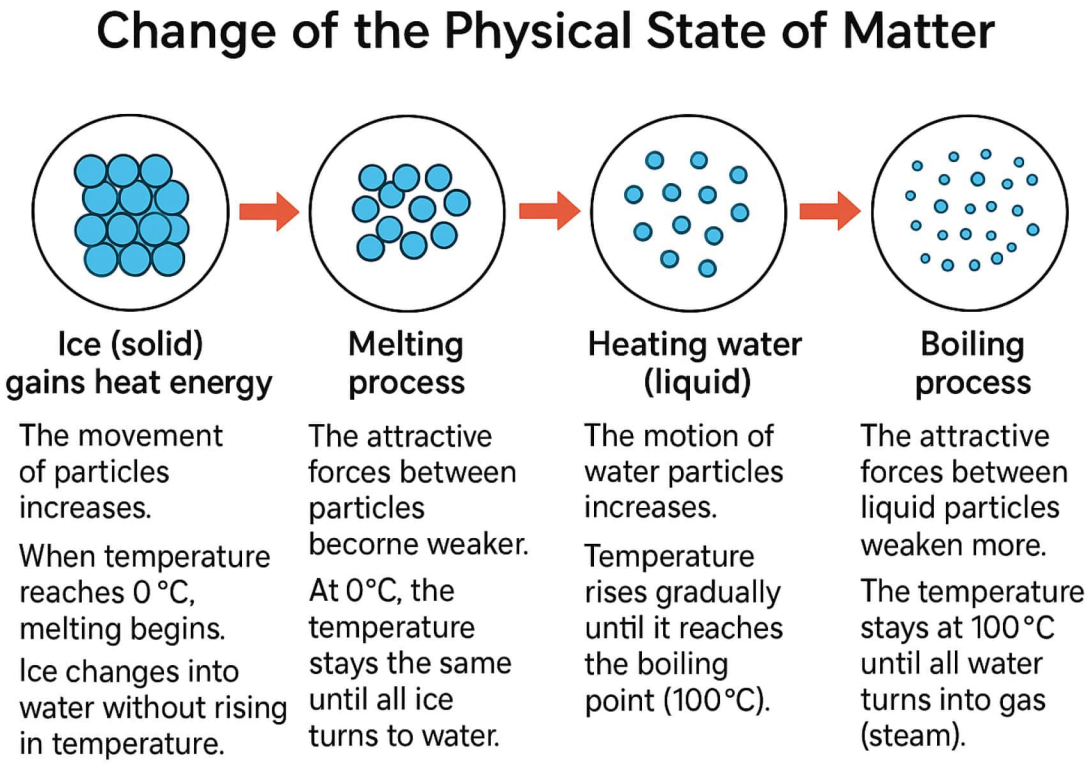
Unit 1 – Lesson 2

The diagram shows what happens to water in its three states when it gains heat energy:


Change of the Physical State of Matter
Ice (solid) gains heat energy
The movement of particles increases.
When temperature reaches 0 °C, melting begins.
Ice changes into water without rising in temperature.
Melting process
The attractive forces between particles becorne weaker.
At 0°C, the temperature stays the same until all ice turns to water.
Heating water (liquid)
The motion of water particles increases.
Temperature rises gradually until it reaches the boiling point (100°C).
Boiling process
The attractive forces between liquid particles weaken more.
The temperature stays at 100°C until all water turns into gas (steam).

The effect of raising the temperature on the kinetic energy of water particles.

In general, it is noted that:

- When matter in one of its states gains heat energy, the kinetic energy of its particles increases, so its temperature rises, and vice versa.
- With the continued absorption of more heat energy by the liquid substance, its temperature rises gradually until it reaches the boiling point.
- With the continued loss of heat energy by the liquid substance, its temperature decreases gradually until it reaches the freezing point.
- During the processes of melting and boiling, the temperature remains constant, as the absorbed heat energy works to weaken the forces of attraction between the particles (molecules) of the substance.

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Question & Answer

Q: From the opposite diagram: -

Chart (1)

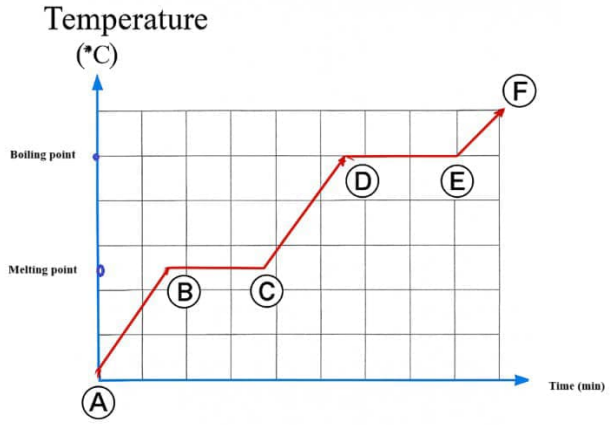
Identify the symbol for each of the two processes in which the energy of matter particles increases.

- The increase in particle energy leads to a rise in the temperature of both ice and water, as occurs in the processes of **melting and boiling (evaporation).**

- The particle energy increases in both processes (Y) and (Z).

Graphical Representation of Heating a Substance under Specific Conditions

(Graph showing Temperature (°C) vs. Time (min) with points A, B, C, D, E, F, and labels for Melting Point and Boiling Point)



Period	Analysis
AB	- A rise in temperature occurs from (A) to (B).

- The substance is in the solid state.

- The particles of the solid substance vibrate more in their positions due to gaining thermal energy, which leads to an increase in their kinetic energy.

Period	Analysis
BC	- No change in temperature occurs from (B) to (C),

because the absorbed thermal energy is consumed in weakening the forces of attraction between the particles of the solid substance until it completely transforms into the liquid state.

- The substance is in both solid and liquid states.

- Point (B) or (C) represents the melting point of the substance.

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Period	Analysis
CD	- A rise in temperature occurs from (C) to (D).

- The substance is in the liquid state.

- The speed of the liquid substance particles increases due to gaining thermal energy, which leads to an increase in their kinetic energy.

Period	Analysis
DE	- No change in temperature occurs from (D) to (E)

because the absorbed thermal energy is consumed in weakening the forces of attraction between the particles of the liquid substance until it completely transforms into the gaseous state.

- The substance is in both liquid and gaseous states.

- Point (D) represents the boiling point of the substance.

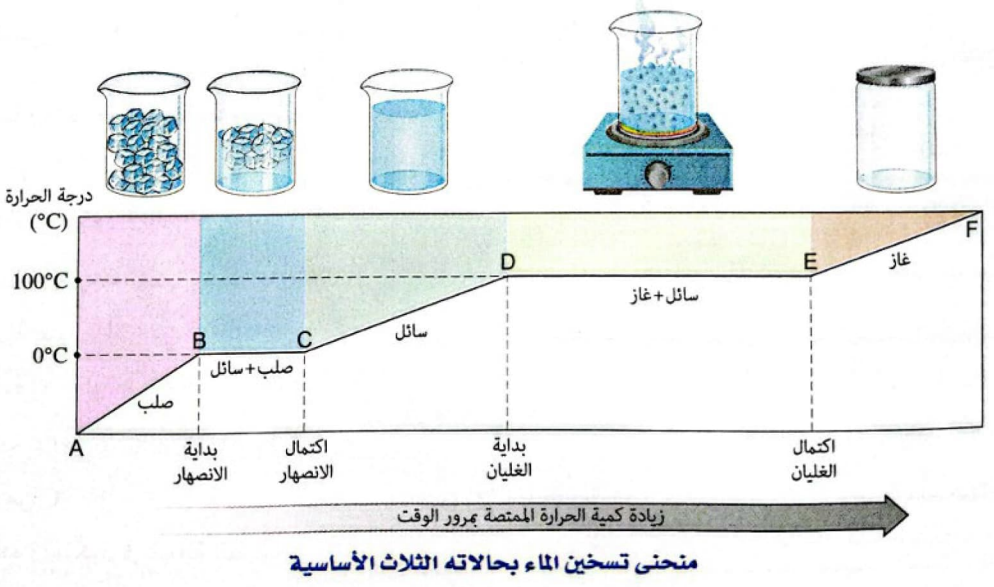
Period	Analysis
EF	- A rise in temperature occurs from (E) to (F).

- The substance is in the gaseous state.

- The speed of the gaseous substance particles increases due to gaining thermal energy, which leads to an increase in their kinetic energy.

تطبيق

التمثيل البيانى لمنحنى تسخين الماء بحالاته الثلاث الأساسية فى ظروف معينة :



منحنى تسخين الماء بحالاته الثلاث الأساسية

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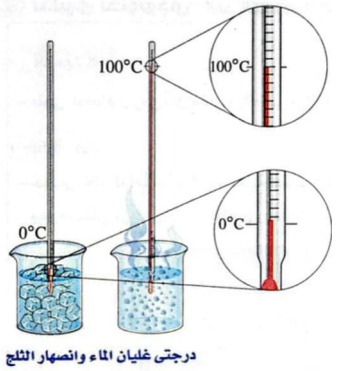
Factors Affecting the Melting and Boiling Points of Substances

Every pure substance has two constant values for its melting and boiling points at standard atmospheric pressure. These two values are affected by several factors, including:

1- Atmospheric Pressure 2- The Purity of the Substance

1. The Relationship Between Atmospheric Pressure and Melting/Boiling Points

- At sea level, the air pressure is described as standard atmospheric pressure. At this pressure:
    - The melting point (freezing point) of water is **0°C**
    - The boiling point of water is **100°C**

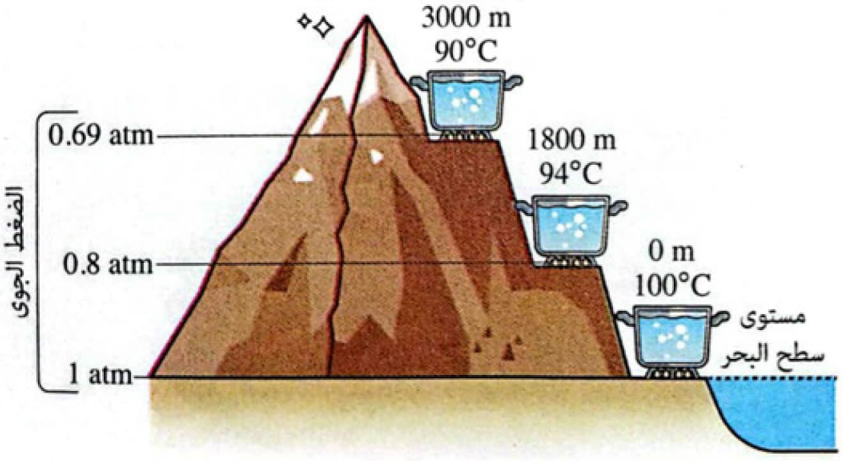


As we rise higher above sea level:

- The atmospheric pressure decreases below the standard pressure.
- As a result:
    - The boiling point of water decreases from 100°C, with the temperature decreasing by approximately 1°C for every 300 m of altitude.
    - The melting point of ice (frozen water) increases above 0°C, and vice versa.

Life application:

The lower atmospheric pressure in high mountainous areas leads to a decrease in the boiling point of water below 100°C. The boiling point decreases the higher we go (as shown in the adjacent figure).



انخفاض درجة غليان الماء تبعًا لانخفاض الضغط الجوى

Question & Answer

What is the boiling point of water at the highest peak of the Alps, which is approximately **4800 m**?

- The temperature decreases by **1°C** for every **300 m** of altitude.
- The total decrease in temperature: **4800 ÷ 300 = 16°C**.

The boiling point of water at the highest peak of the Alps is: **100 - 16 = 84°C**.

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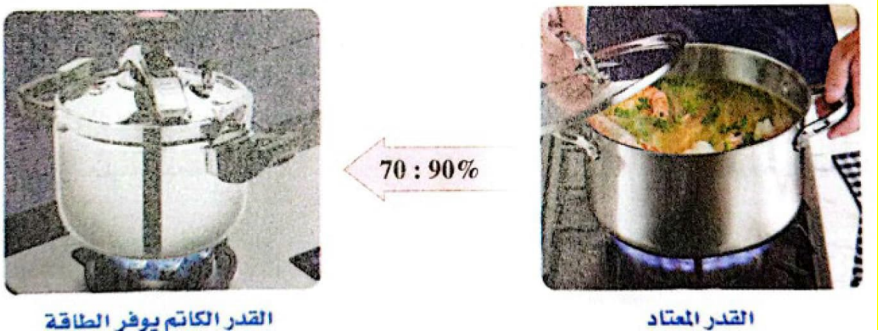
Technological Applications: The Pressure Cooker حلة الضغط



Importance

- Cooks food in less time compared to cooking in an ordinary pot, which saves fuel (energy).

How it Works

- It traps water vapor inside during the cooking process, which leads to an increase in pressure and consequently raises the boiling point of water **above 100°C**.
- This reduces the cooking time and helps save fuel.

2. The Relationship Between the Purity of a Substance and its Boiling/Freezing (Melting) Points

Impurities affect the forces of attraction between the particles of a substance.

This leads to a change in the amount of energy required to change its state.

Consequently, both its melting point and boiling point are affected.

Therefore, the purity of substances is verified by comparing their measured boiling point or melting point to the constant standard values for the pure substance.

*** The elevation of the boiling point and the depression of the freezing point depending on the concentration of the solution. يعتمد الارتفاع في درجة الغليان او الانخفاض في درجة التجمد على تركيز المحلول**

Understanding Two Phenomena:

- **What happens when...**
  - 342 g of sucrose (table sugar) is dissolved
  - in 1 kg of distilled water to form a solution.
- **The boiling point of the solution rises by 0.5°C**
  - Meaning it becomes **100.5°C**
- **The freezing point of the solution is depressed by 1.86°C**
  - Meaning it becomes **-1.86°C**

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Matter Transformations: Reversible Processes

• You may notice water droplets found on a cold glass surface or dew on plant leaves in the early morning, where water vapour condenses when it loses heat due to contact with a cold surface and turns into liquid droplets.

• Water also freezes in the freezer of the fridge when it loses heat (thermal energy).

• In the melting process, a solid substance gains a quantity of thermal energy either by heating or from the surrounding medium and converts to liquid state.

• In the boiling process, a liquid substance gains a quantity of thermal energy by heating and converts to gaseous state.

Are these two processes reversible?

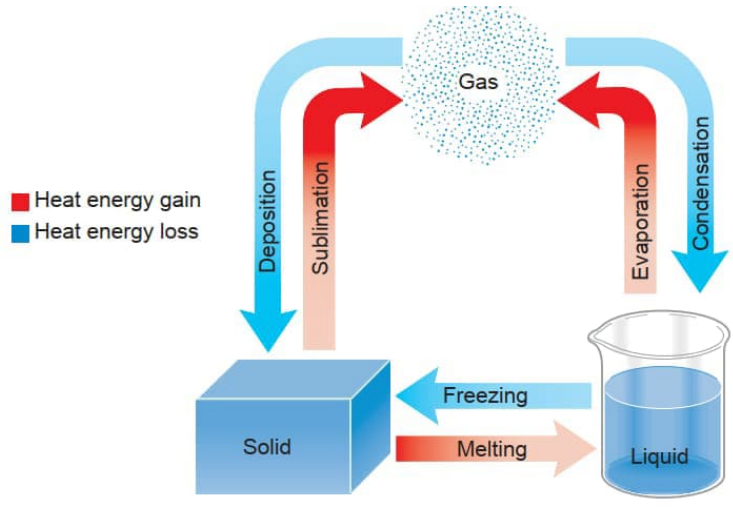
The conversion of matter from one state to another is a reversible process.

Melting and freezing processes are reversible processes, as are evaporation and condensation.

The conversion of a substance from one state to another is a physical change that is not accompanied by a change in the composition of its molecules or the formation of new substances. For example, water molecules (H_2O) do not break down into hydrogen and oxygen molecules when they change from one physical state to another.

In chemical changes, there is a change in the composition of the substance, and new substances are formed.

The conversions of matter can be illustrated in the figure:



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Cross-Cutting Concepts: Cause and Effect

Loss of thermal energy of water vapour molecules in air (Cause),

leads to its condensation in the form of fog, dew or clouds (Effect).

The change of matter from the solid state to the gaseous state directly without passing through the liquid state is known as sublimation, as in the sublimation of dry ice (Figure), which is carbon dioxide in its solid state and the sublimation of iodine element.

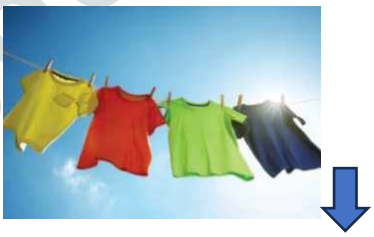
While the change of a substance from the gaseous state directly to the solid state without passing through the liquid state is known as deposition as in the formation of frost.

Boiling and Evaporation:

In the boiling process, the liquid turns into vapour at a certain temperature called the boiling point,

at which point the bonds between the molecules of the liquid break down.

You can notice that leaving wet clothes exposed to the air makes them dry without reaching the boiling point.



Boiling Process	Evaporation Process
(1) The process of converting matter from the liquid state to the gaseous state at a specific point, which is the boiling point.	(1) The process of converting matter from the liquid state to the gaseous state at any temperature below the boiling point.
(2) Occurs for all molecules of the liquid.	(2) Occurs for molecules present on the surface of the liquid.
(3) Occurs by means of thermal energy obtained from a heat source.	(3) Occurs by means of thermal energy obtained from the surrounding medium or a heat source.
(4) Takes a relatively short time.	(4) Takes a relatively long time.
(5) Is accompanied by the formation of air bubbles (gaseous inside the liquid).	(5) Is not accompanied by the formation of air bubbles (gaseous inside the liquid).

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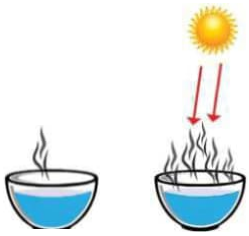
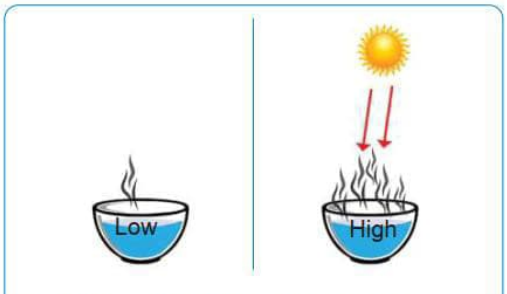
- Factors which affect the rate of evaporation of liquids,

1- Temperature
2- The surface area of the liquid exposed to the action
3- Humidity الوحيدة اللي عكسي
4- Air currents

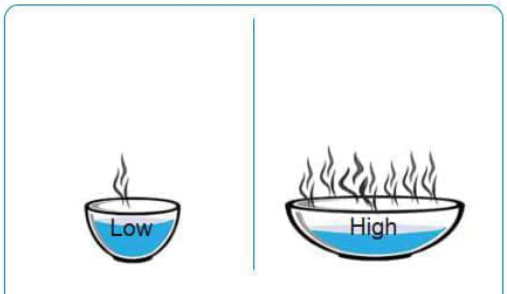
Cumulative knowledge

- **Controlled variable :** A factor that remains constant during an experiment.
- **Independent variable (cause) :** The factor that is changed during the experiment.
- **Dependent variable (effect):** The factor that changes depending on the independent variable.

1-Temperature  (1) (2)	**2- Surface Area of the Liquid Exposed to Evaporation** (1) (2)
Controlled Variable ثابته	
• Liquid surface area • Humidity • Air currents	• Temperature • Humidity • Air currents
Independent variable لما تتغير	
Temperature difference	Liquid surface area
Dependent variable ده يتغير	
The evaporation rate in pot (2) is greater than in pot (1)	The evaporation rate in pot (1) is greater than in pot (2)
Conclusion:	
The evaporation rate increases when the temperature rises	The evaporation rate increases when the surface area of the liquid subject to evaporation increases
Explanation:	
Temperature increases, because the kinetic energy of molecules increases, thereby increasing the number of molecules that have sufficient energy to escape from the surface of the liquid.	The surface area of the liquid exposed to air increases, as the number of molecules that can gain heat energy from the surrounding medium increases and be released from the surface of the liquid.



Increased temperature increases the rate of evaporation



Increasing the surface area of the liquid increases the rate of evaporation

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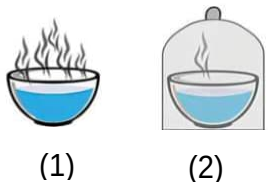
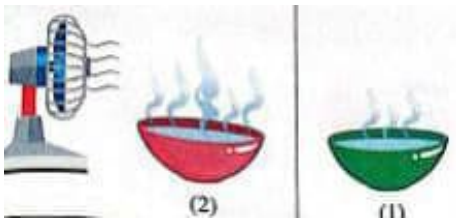
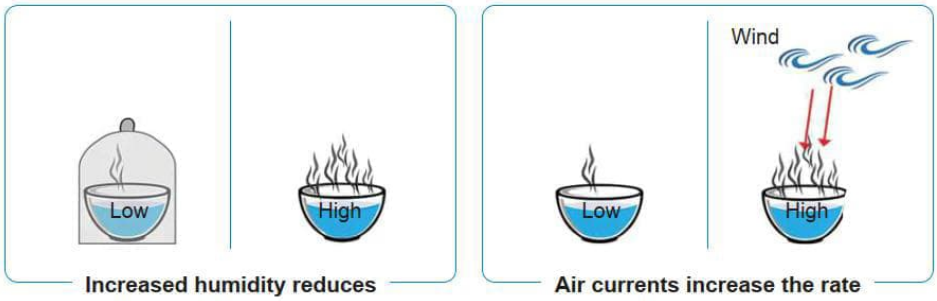
1-Humidity	2- Air currents
 (1) (2)	 (2) (1)
Controlled Variable ثابته	
• Liquid surface area • Temperature • Air currents	• Liquid surface area • Humidity • Temperature
Independent variable لما تتغير	
Difference in humidity percentage of water vapor present in the air	Air currents
Dependent variable ده يتغير	
The evaporation rate in vessel (1) is greater than in vessel (2)	The evaporation rate in vessel (2) is greater than in vessel (1)
Conclusion:	
The evaporation rate increases when the humidity decreases	The evaporation rate increases when the speed of air currents increases
Explanation:	
The retention of water vapor in the air of vessel (2) reduces the evaporation rate, while the escaping water vapor from the uncovered vessel (1) increases the chances of more surface molecules evaporating	Air currents increase the evaporation of more water molecules from the surface of the liquid



** Integration with Hydrology (Science of studying water)

The change of water from one state to another, such as evaporation, condensation, freezing, and melting, are fundamental processes in the water cycle in nature. The water cycle in nature directly affects many weather factors.

** Technological Application: Instant coffee

Instant coffee is named as such because it dissolves quickly in water compared to regular coffee. It is manufactured by exposing sprayed concentrated coffee extract to extremely hot dry air (around 250°C), where the increase in the surface area of the spray droplets exposed to hot air increases the rate of evaporation and the formation of solid instant coffee crystals.

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